



Integrated Design Center / Mission Design Laboratory

PACE 2012

Attitude Control

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N A S A G O D D A R D S P A C E F L I G H T C E N T E R





Subsystem Agenda

M i s s i o n D e s i g n L a b o r a t o r y

- Overview
- Block Diagram
- Subsystem Description
 - Design Drivers
 - Mode Descriptions
 - Actuator Sizing
 - Components
- Future work



Subsystem Overview

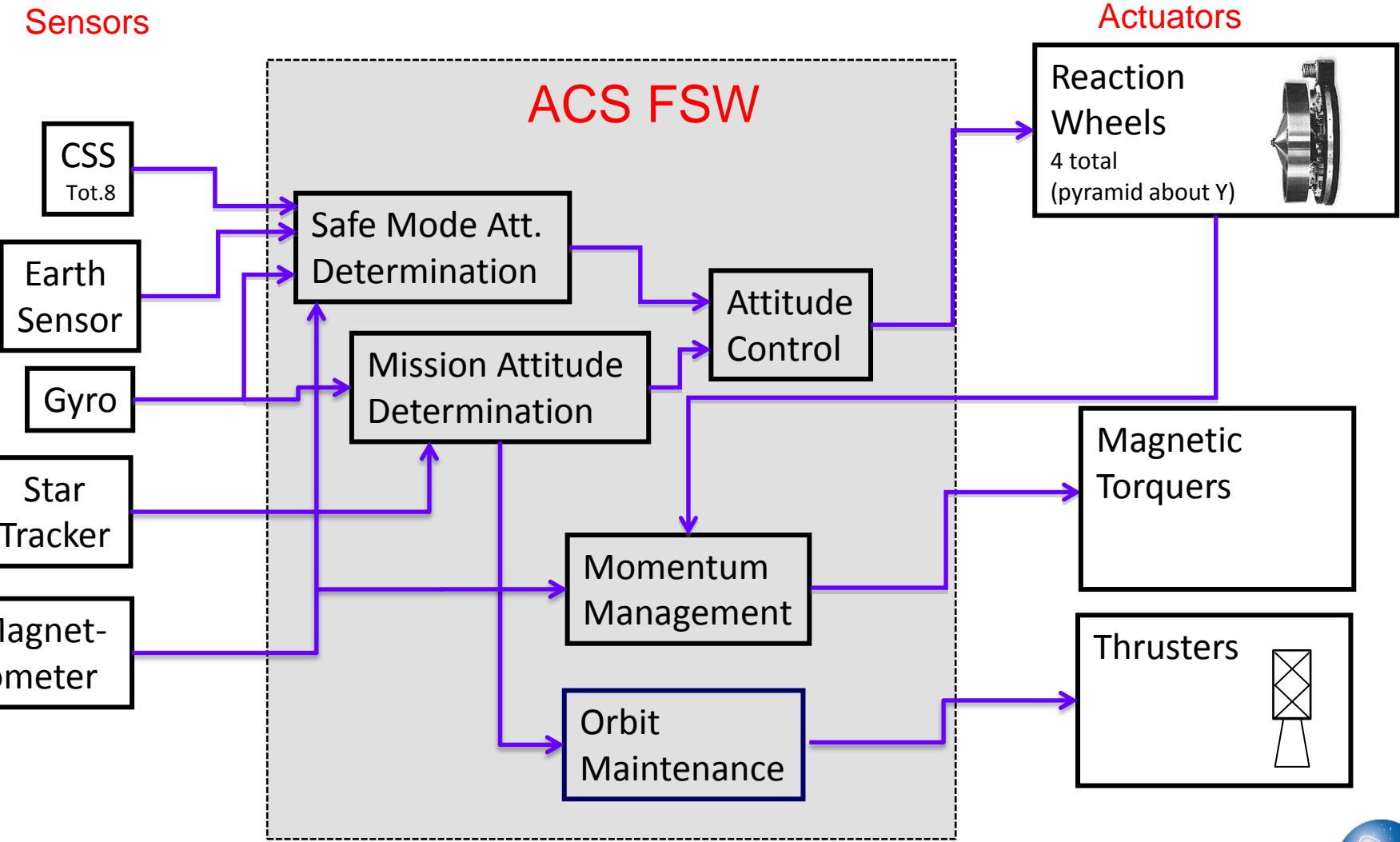
M I S S I O N D E S I G N L A B O R A T O R Y

- **Three-axis stabilization**
 - Star tracker-IRU are primary sensors
 - Reaction wheels are primary actuators
 - Magnetic torquers for momentum management
 - Coarse sun sensors, magnetometer, Earth sensors are acquisition and backup sensors
- **Wheel sizing driven by OCE tilt at orbit noon**
 - OCE tilted 40 deg in 15 seconds
 - Lunar cal maneuver less stressing
- **Key pointing requirement is a stability requirement derived from image registration requirement**
 - 25 arcsec over 0.14 sec (7 Hz)
 - Control, knowledge requirements assumed typical for EOS class of spacecraft
 - 0.1 deg control, per axis
 - 40 arcsec knowledge per axis



Subsystem Block Diagram

M I S S I O N D E S I G N L A B O R A T O R Y



Design Drivers

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- **OCE tilt at each orbit noon**

- Tilt from -20 deg intrack (pitch) to +20 deg intrack in 15 seconds
- May be accomplished by tilting whole S/C...
 - Requires 12.4 Nm torque, 93 Nms momentum storage in pitch axis
 - Requires counter-tilt of Polarimeter to maintain nadir pointing
- Or by OCE tilt mechanism
 - Less wheel authority required
- *Study baseline was to have an OCE tilt mechanism*

- **Lunar calibration, monthly**

- Accomplished by pitch-around during night segment of orbit
 - 360 deg in LVLH = 180 deg in inertial frame (+0.06 deg/sec)
 - Slow down when Moon moves through OCE FOV (1 deg/min = 0.0167 deg/sec) for 1.5 min

Mode Descriptions

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- **Sun Acquisition/Sun Safe Mode**

- Sun sensors (CSS), magnetometer (TAM), gyro
- Park solar array, point -Z (Zenith) face to Sun

- **Earth Acquisition/ Earth Safe Mode**

- Earth sensor (ES), TAM, gyro
- Point +Z face to Earth, point solar array to Sun

- **Normal/Science Mode**

- Star tracker, gyro
- TAM for momentum management
- CSS, ES for failure detection
- Point +Z face to Earth, track solar arrays at orbit rate

- **Lunar Cal Mode**

- Star tracker, gyro
- Pitch slew-around during night portion of orbit

- **Orbit Adjust/Deorbit Mode**

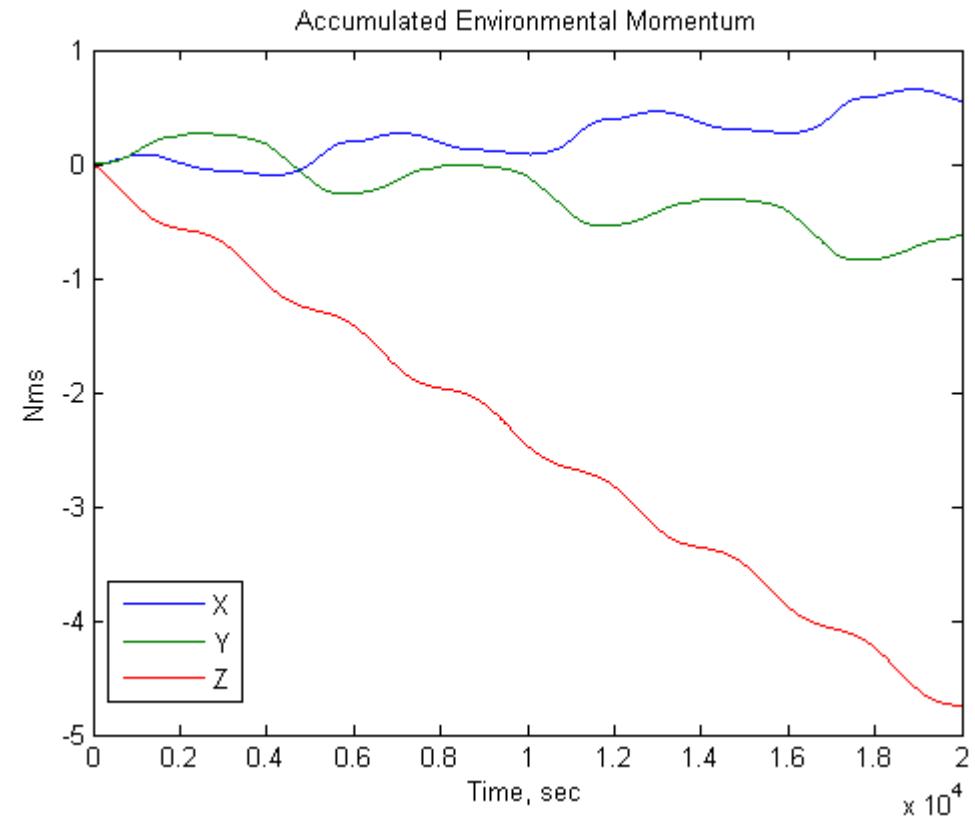
- Star tracker, gyro
- Thrusters used for orbit control and attitude control
- Hold attitude relative to LVLH to enable desired thrust direction



Actuator Sizing: Environmental Torques

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- Gravity-gradient torque is dominant external disturbance
- 20 Nms accumulated per day
- Cyclic portion stored, released by wheels
 - 0.4 Nms required
- Secular portion unloaded by magnetic torquers
 - 30 A-m² required
- Wheel sizing will be driven by slews, not by environmental torques



Wheel Sizing: Slews

M I S S I O N D E S I G N L A B O R A T O R Y

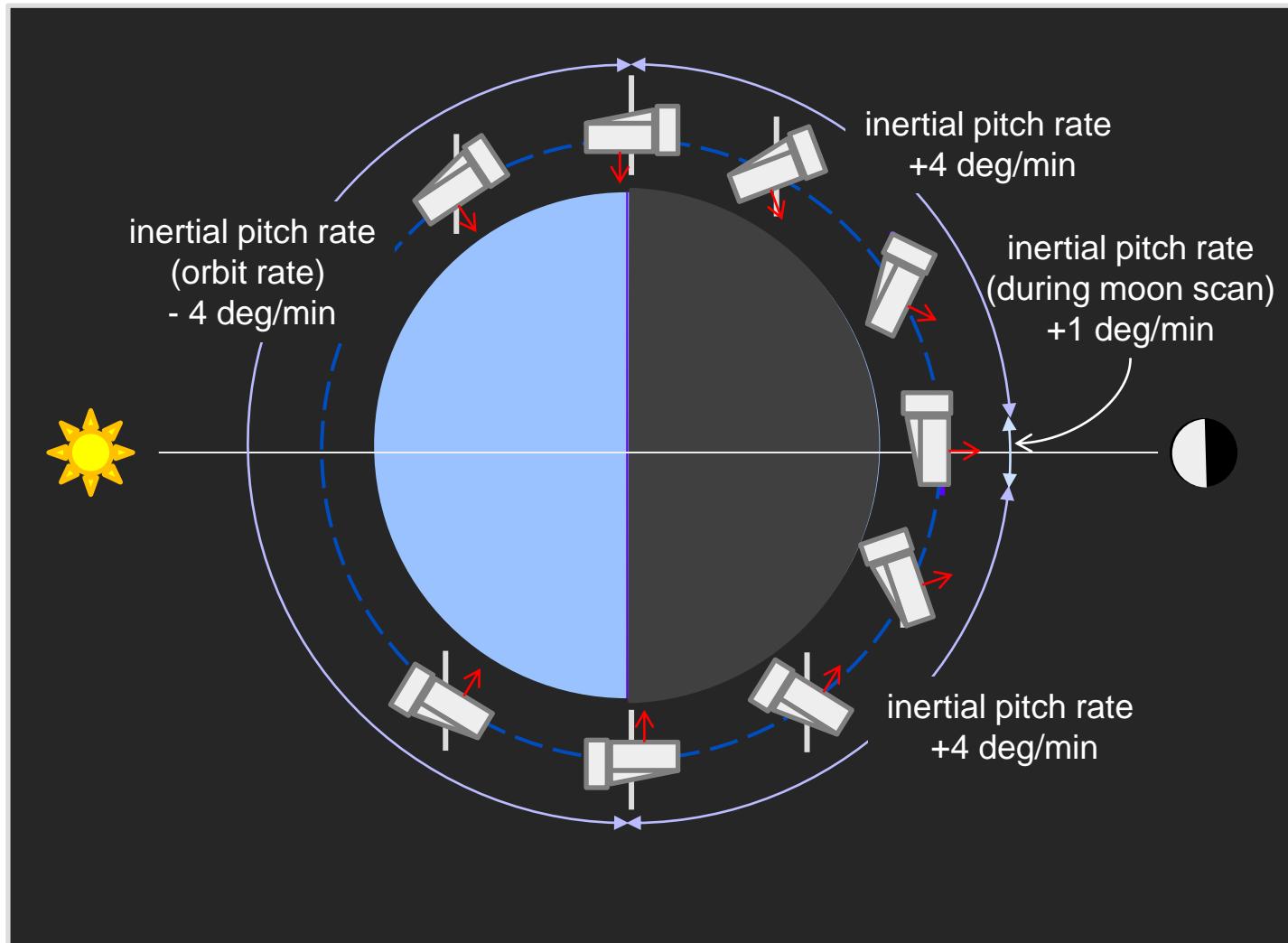
- **OCE Tilt: 40 deg in 15 sec with Reaction Wheels**
 - S/C Moment of Inertia = 1045 kg-m^2
 - Assume torque-limited slew
 - Torque required: 12.4 Nm ($\sim 50 \times$ E-wheel authority)
 - Momentum storage required: 93 Nms
 - Recommendation: Don't do it
- **OCE Tilt: 40 deg in 15 sec with Tilt Fixture**
 - OCE Moment of Inertia $\sim 50 \text{ kg-m}^2$
 - Tilt fixture should be capable of much larger torques than reaction wheels
 - But wheels still need to counter torque and momentum imparted by tilt fixture
 - Minimum torque required: 0.62 Nm ($\sim 2 \times$ E-wheel authority)
 - Minimum momentum storage required: 4.6 Nms
 - This is a feasible option
 - Requires wheel pyramid biased for increased pitch authority: this is routinely done.
- **Lunar Calibration:**
 - Change pitch rate from orbit rate (-0.06 deg/sec) to pitch-around rate (+0.06 deg/sec) with candidate wheel ($\text{Trq} = 0.3 \text{ Nm}$, $H = 26 \text{ Nms}$)
 - Requires ~10 seconds
 - Slow pitch-around rate to 1 deg/min for 1.5 minutes to sweep across the Moon
 - Note: May require small yaw maneuver to center Moon in OCE FOV
 - No impact to ACS hardware
 - Small impact to ACS software





Lunar Calibration Maneuver

M i s s i o n D e s i g n L a b o r a t o r y





ACS Components

M i s s i o n D e s i g n L a b o r a t o r y

Component	Vendor	Model	Quantity
Gyro	Northrup Grumman	SSIRU	1
Star Trackers	Ball Aerospace	CT-631	2
Coarse Sun Sensors	Adcole		8
Magnetic Torquers	Goodrich	TR60CFR	3
Reaction Wheels	Goodrich	TW-26E300	4
Magnetometers	Goodrich	IM-103	2
Earth Sensors	Barnes	13-470	3



Future work

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- **OCE Tilt: S/C ACS design will need feedforward compensation to minimize transients due to OCE tilt**
- **Wheel configuration should be optimized to satisfy disparate requirements**
 - Pitch torque authority for OCE tilt
 - Roll momentum capacity for contingency momentum compensation
 - Avoid being a jitter source, as always

